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Stability of Velocity in the Major Industrial Countries

A Kalman Filter Approach

EDUARD J. BOMHOFF*

Forecasting models are estimated using annual data for the income velocity of money in seven major industrial countries. The predictions are conditional on the realized value of the long-term domestic government bond rate. These forecasts did not deteriorate over the period 1980–88, compared with the earlier postwar period. Velocity of M1 is found to be very interest elastic in almost all countries; velocity of M2, less so. The specifications (based on Kalman filters) point to a nonconstant trend in velocity, raising questions about the assumptions required for the cointegration techniques used in other research on money demand. [JEL F31, E52, E41]

In the early 1980s many economists became convinced that the demand for money schedule was too unstable to be used for policy purposes. One reason was the influential article by Cooley and LeRoy (1981), which cast serious doubts on the identification of a demand for money function. Another cause was the apparent failure of monetary models to explain movements in floating exchange rates, in particular changes in the external value of the U.S. dollar. Also, many demand for

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money relations for U.S. M1 or M2 appeared to break down when used for postsample forecasting, particularly those models that incorporated a small or zero interest rate elasticity. Finally, domestic financial deregulation or international currency substitution was claimed to have shifted the demand for money in an unpredictable manner.

Prescriptions for monetary policy that are formulated in terms of a path for some monetary aggregate must be based on a demand for money function. Doubts about the stability of that function generate doubts about such recipes for policy. This is one reason for the interest in policy prescriptions that are based on targets for interest rates or exchange rates, because these policy rules can (under sometimes unattractive assumptions) be derived from macroeconomic models that do not require identification of a demand for money schedule, or precise knowledge about the interest rate or income elasticities of the demand for money.

Statements about the stability or otherwise of the relationship between money and nominal income are conditional on the selection of countries in the data set and on the type of statistical analysis performed. Here, I have applied identical specifications to annual postwar data for all seven major industrial countries (Group of Seven), using both M1 and M2.[1] The statistical methodology in the paper reflects an important difference of opinion regarding the demand for money function.

Some researchers do not reject the hypothesis that the levels (of the natural logarithms) of money, income, and possibly a relevant interest rate are cointegrated, meaning that a regression of the level of real balances on the level of income (and the opportunity cost variable) is permissible.[2] Others prefer to work in terms of first differences of money, income, and interest rates without reliance on a long-term relationship in terms of the levels (see, for example, Rasche (1987) and Hetzel and Mehra (1989) for the United States). Finally, the monograph by Bordo and Jonung (1987) on the long-run behavior of velocity in many countries shows that velocity has a stochastic trend. Unless explanatory variables can explain all changes in the rate of growth of velocity—and the work by Bordo and Jonung suggests that neither income nor institutional variables that represent monetization or economic development can provide more than a partial explanation—it follows that regressions in

[1] See Boughton (1991), who uses data from five of the seven countries; see also Hendry and Ericsson (1991) for the United Kingdom only, and Hoffman and Rasche (1989) for the United States.

[2] When no danger of confusion exists, the words "natural logarithm of" will be omitted in the ensuing discussion.

first differences are misspecified; one would have to difference at least twice.

The simple fact that there are three co-existing schools of thought on this particular issue proves how hard it is to resolve the dispute with least-squares regression techniques. Recall that the natural context for any least-squares model is that of stationary variables, because least-squares regressions for nonstationary variables have to work with a system matrix $X'X$ that is a function of the number of data points. Such regressions do not satisfy ergodicity, meaning that it is not plausible that a single collection of historical data can be used for the estimation of coefficients with distributions that relate to repeated sampling.[3]

Of course, each differencing operation increases the probability that the transformed series are stationary. But, if the relationship when specified in terms of levels is subject to both temporary and permanent disturbances, differencing results in a deterioration of the signal-to-noise ratio and less well-determined coefficients.

In contrast to linear regression techniques, Kalman filters and smoothers are designed to work with nonstationary data, because the filters and smoothers produce distributions of the so-called state variables that are conditional on the previous realization of the states. For that reason, nonstationarity in itself presents no problem, and ergodicity can be satisfied, implying that the distributions of the coefficients have a meaningful interpretation. The only reason that Kalman filtering has not yet become the natural way to model multivariate time series has been the technical difficulty of combining estimation of the states with estimation of other parameters required to run the filter successfully.

In this paper I present a method for estimating states and parameters jointly, using smoothing algorithms developed by Maybeck (1979, 1982), together with an estimation technique developed by Dempster, Laird, and Rubin (1977), and adapted to the Kalman filter case by Shumway and Stoffer (1982).

The Kalman filter model will be estimated in terms of levels, with allowance for three types of shocks to velocity (V): (1) temporary shocks to the level of V; (2) permanent shocks to the level of V; and (3) permanent changes in the trend of V. Note that type (2) can also be described as representing temporary disturbances to the rate of growth.

[3] Durlauf and Phillips (1988) provide an excellent theoretical analysis of the difficulties that arise when ordinary least squares are applied to nonstationary time series with the possibility that the errors are also nonstationary and nonergodic. See also Plosser and Schwert (1979) and Nelson and Plosser (1982). This line of research originated with Paul Newbold (see Granger and Newbold (1974)).

The variances of the different types of shocks and, hence, their relative importance will be estimated on the basis of the data. In this way, the methodological difficulties associated with indirect tests for nonstationarity or cointegration are avoided; the data will tell us whether it is useful or not to account for stochastic changes in the trend.[4]

However useful for dealing with nonstationarity and mixtures of different types of shocks, the Kalman filter cannot deal with the issues raised by Cooley and LeRoy (1981). These authors emphasized two complications that hamper empirical investigations of the demand for money schedule: (1) disentangling demand and supply of money may be impossible;[5] and (2) measurement errors in the explanatory variables affect the estimated coefficients in the demand for money relation.

Perhaps the best response is to give up the ambition to *estimate* a demand for money function and try only to *forecast* the income velocity of money. In this paper I take the position that forecasts of velocity remain useful, even though it may not be possible to classify the forecast formula as an inversion of the demand for money schedule. Thus, the forecasts may be based on some mixture of demand and supply schedules, and the coefficients will indeed be sensitive to measurement errors in the right-hand-side variables and possibly to the Lucas critique.[6] Hence, the principal connections between the forecasting formulas and economic theory are the choice of explanatory variables—legitimized by their association with the demand for, or perhaps the supply of, money—the maximum length of any lags in the formulas, and perhaps prior distributions on some of the coefficients.

The remainder of the paper is organized as follows. Section I introduces a multivariate Kalman filter technique that can be used to estimate a relationship between the level of V and the level of the interest rate. In Section II, I present the results of implementing this multivariate Kalman filter for the velocity of M1 and M2 in all of the Group of Seven countries, using annual data. Section III tests a number of simple hypotheses regarding the stability of velocity and the size of the forecast errors in velocity during the 1980s. Section IV draws some statistical and economic conclusions.

[4] See Swamy, von zur Muehlen, and Mehta (1989) for a critical methodological discussion of cointegration tests.

[5] See, for example, Hamilton (1989) for a brief analysis of why standard money demand equations are a mixture of supply and demand effects.

[6] Neither issue can be circumvented with the use of instrumental variables (see Cooley and LeRoy (1981)).

I. A Kalman Filter Model for Velocity

Consider the simplest possible relationship between real balances, real income, and an interest rate:

$$p_t + y_t - M_t = V_t = c + \alpha tr_t + \theta i_t + u_t. \tag{1}$$

In equation (1), p_t represents the natural logarithm of the price level in an economy; y_t is the log of a measure of income appropriate to the demand for money; M_t is the log of the money supply; and hence, V_t is the log of the income velocity of money. On the right-hand side, c represents a shift term in the regression; tr_t is a linear trend for the log of V; i_t is the log of some relevant interest rate; and u_t is the residual in the regression; α and θ are coefficients to be estimated.

If one models in terms of levels, the residual part of the equation has to be accepted as nonstationary. Time-varying stochastics offer the best chance to cope with the dynamic aspects of the demand for money listed above. One way to embed the linear least-squares equation (1) in a richer dynamic model is to change to the state-space formulation. The state vector is composed of all regression coefficients. The state-transition matrix would be the unit matrix in the case of recursive least squares without correction for serial correlation, but can be different in order to represent dynamic features that are hard or impossible to model in the least-squares context.

The general state-space notation is as follows:

$$V_t = (1 \quad 0 \quad i_t)\begin{pmatrix} c_t \\ tr_t \\ \theta_t \end{pmatrix} + u_t \qquad \text{var}\,(u) = R \tag{2}$$

$$\begin{pmatrix} c \\ tr \\ \theta \end{pmatrix}_{t+1} = \begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}\begin{pmatrix} c \\ tr \\ \theta \end{pmatrix}_t + \begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix}\begin{pmatrix} w_1 \\ w_2 \\ w_3 \end{pmatrix}_t$$

$$\text{var}\begin{pmatrix} w_1 \\ w_2 \\ w_3 \end{pmatrix} = \begin{pmatrix} Q_1 & 0 & 0 \\ 0 & Q_2 & 0 \\ 0 & 0 & 1 \end{pmatrix}. \tag{3}$$

Equation (2) is the observation equation. It states that the level of the log of velocity, V, equals the sum of a shift parameter, the product of the interest rate elasticity, θ, and the long-term interest rate, i_t, and a residual term, u_t. This observation equation is identical to an ordinary regression equation.

The Kalman filter methodology adds equation (3), the so-called stateupdate equation. It shows how three state variables change from period to period. The equation has a predetermined part and a stochastic part. In the predetermined part, the shift parameter is adjusted upwards in each period by the amount tr_t, which represents a trend. In the stochastic part of equation (3), the trend term, tr_t, is subject to a stochastic shock, w_2, and the shift parameter is subject to permanent stochastic shocks, w_1. The interest rate elasticity is not subject to stochastic shocks over time.

The user of a Kalman filter is asked to provide estimates of the variances Q_1, Q_2, and R. The Kalman filter then processes the data "on line" and produces estimates of the state variables—here, the shift parameter, the trend and the interest elasticity—and their variance-covariance matrix, P_t.

The variances, Q_1, Q_2, and R may be chosen in such a way that the specification becomes equivalent to either equation (1) in terms of the levels or the same specification in terms of first or second differences. The Kalman filter specification of equations (2) and (3) thus includes both the levels and the first-difference specification. Other statistical techniques for comparing levels and first-difference specifications suffer from the disadvantage that the two competing hypotheses are nonnested.

The Kalman filter model may be rewritten as follows:

$$\Delta V_t = \theta \Delta i_t - 1.0 (V_{t-1} - m_{t-1} - \theta i_{t-1}) + e_t. \tag{4}$$

In equation (4), m_t represents a stochastic trend, subject to the three types of shocks discussed before: temporary to the level, permanent to the level, and permanent to the rate of growth. The equation shows that the state-space formulation is equivalent to an error-correction model for money demand. In this particular simple case, the adjustment parameter happens to be unity (and the coefficient on i_{t-1} equals the coefficient on Δi_t), because with annual data and a stochastic trend there is no serial correlation in the residuals and, hence, no need for lagged terms. An important difference with standard error-correction models is the behavior of the intercept, m_t, which is constrained to be constant over time in such models. Hence, the Kalman filter formulation incorporates all error-correction models—one could allow for lagged vales of velocity and opportunity cost variables—but it is richer in one crucial respect because it allows for permanent shocks to the level and rate of growth of velocity.

II. Velocity in the Group of Seven Countries

All data are taken from the *International Financial Statistics* (*IFS*) tape produced by the International Monetary Fund (IMF). Starting points for the analysis were dictated by data availability on the tape: the terminal

Table 1. *Discontinuities in Money Series Data*

Country	Data Availability	
	M1	M2
United States	—	1959
United Kingdom	1981	1975
France	1958 1969 1977	1958 1969 1977
Canada	1968	1967 1968

year is 1988. Because of discontinuities in some of the monetary series, I have inserted a dummy variable for each of the nontrivial breaks in a series for M1 or M2.[7] Since estimation is in terms of levels, the dummies are of the type $\{0, 0, .. 0, 1, 1, .. 1, 1\}$. Dummies have been inserted because of the following discontinuities in the money series, as indicated by the *IFS* tape (Table 1).

The economic model is the simplest possible one. The income elasticity of money demand is fixed at unity, and a single interest rate is used to represent the opportunity cost of money, using the simplifying assumption that the own rate of return on money in each country is constant over time at the margin. With such simple assumptions, the resulting models will not be the optimal forecasting tools for velocity. However, the results from these minimal specifications may contribute more convincingly to the debate about the predictability of velocity, because uniform and simple models for seven different countries are less subject to the suspicion of having been based on data mining than multiparameter models with extensive lag structures and many free parameters that are tuned to the actual data in each country.

The only free parameters in the models are the interest elasticity, which is assumed to be constant over time, and two variance terms—the variance of the permanent shocks to the level of the series, and the variance of the permanent shocks to the trend in velocity.[8]

The income elasticity of money is not a free parameter in this Kalman

[7] Note that the dummies relate only to breaks in one of the variables in the definition of velocity, not to observed outliers in the estimated statistical models.

[8] The variance of the temporary shocks to the level of velocity could be seen as a third variance parameter, but the models are homogeneous of the first degree in all the variance and covariance terms. Hence, this variance is best viewed as computed ex post from the results of the Kalman filter.

filter model. I hypothesize that financial innovations lead to changes in velocity trends that are spuriously picked up by nonunitary income elasticities in the traditional money demand specifications. The principal attraction of this hypothesis is that it is not troubled by the substantial differences between the income elasticities in different countries over identifical time periods in traditional models that do not allow for stochastic trends, but include the income elasticity as a free parameter.

The exogenous explanatory variable is the domestic yield on long-term government bonds. No experiments were undertaken with other rates of return or with lag structures, and the same specification was imposed for all countries. I have tested for stability of this interest rate elasticity by allowing for a different value before and after 1980. The hypothesis that the interest rate elasticity did not differ between these two subperiods was not rejected for any of the Group of Seven countries.

The analysis is limited to a single opportunity cost variable, and I have made no attempts to incorporate measures for the own return on money. In recent years, many Group of Seven countries have witnessed an increase in the explicit payment of interest on large fractions of M1 and M2, and therefore it would certainly make sense to collect data for the own rate of interest and test for its significance.

The filtering and estimation algorithm consists of five different blocks. First, there is a normal ("forward") Kalman filter that produces an estimate of the state variables at time $T + 1$ (in this case, the shift parameter, the trend, and the interest rate elasticity) based on all the data from time $t = 1$ up to and including time $t = T$. Second, a backward filter is used that generates a backward "forecast" for time T, using all the data from period $T + 1$ through to the final period.

A smoothed estimate of the state at time $t = T$ can be formed by combining the forward and backward filters. In order to generate a meaningful covariance matrix for the smoothed estimates of the states, one has to start both filters with an uninformative prior distribution for the covariance matrix of the states. With this initialization, the smoothing algorithm will reproduce the ordinary least squares (OLS) variance matrix of the parameters (and the OLS residuals) in the special case that all the states are constant and correspond to OLS parameters.[9]

The fourth block of the algorithm uses the results of the Kalman

[9] In this important respect, my program differs from the "stamp" program, developed by Harvey and described in Harvey (1989). His program uses up the first two values of the observed series in order to initialize the two unknown variance terms for the shocks to the level and growth rate of the series. By contrast, I apply a smoother in each iteration of the program, which is computationally more costly but avoids this loss of degrees of freedom in estimation.

smoother to compute adjustments to the three unknown variance terms. I use the expectation maximization algorithm, described by Dempster, Laird, and Rubin (1977) and adapted to the case here by Shumway and Stoffer (1982).[10] Then, the separate forward and backward Kalman filters (blocks 1 and 2) are run again in order to prepare inputs for the Kalman smoother in the next iteration. This process stops when the estimated values of the unknown parameters have converged to their optimal values.[11]

Finally, the fifth block of the algorithm is applied just once. It starts with the optimal values for the interest rate elasticity and all variance terms and uses these inputs for a single run through the data. The forecast errors of this filter are analyzed in Tables 2, 4, 5, and 6. Such a forward filter does use a few inputs that are based on an analysis of the complete sample period: the interest rate elasticity and the relative importance of permanent shocks to the level of velocity versus permanent shocks to its growth rate. However, the final forward filter does not use knowledge about the specific realization of the shocks in the sample. Hence, it should be classified as a recursive method rather than an ex post method such as ordinary least squares or least squares with an error-correction specification.

Table 2 summarizes the results for the Group of Seven countries. For each country the interest rate elasticity is shown for M1 velocity and M2 velocity, together with the estimated standard error of the coefficient. All t-values are significant at the 0.05 level on a two-sided test, except for France, where the interest rate elasticity for M2 is insignificant and the coefficient for M1 has a t-value of 2. In all countries the interest rate elasticity of M2 is smaller than that of M1, except in the United States, where the elasticities are estimated to be about equal. In five of the seven countries the interest rate elasticities for M1 are quite close together (United States, Japan, Germany, United Kingdom, and Italy). The elasticities are higher but still of the same order of magnitude as found in earlier work by den Butter and Fase (1981).

Table 2 also shows the size of the forecast errors. These are conditional on the realized value of the long-term domestic bond yield and the estimated interest rate elasticity and on the optimal estimates of the relative importance of the three different types of shocks that affect velocity. As far as the intercept and the trend in velocity are concerned,

[10] See Nelson (1988) for evidence from his univariate research of U.S. gross national product that optimization with respect to the unknown variances of the different shocks to the level and the shocks to the trend of a nonstationary time series may be a delicate matter. This is a topic for additional research.

[11] See Bomhoff (1990) for further details on the statistical procedure used.

Table 2. *Forecast Errors of Velocity*

	M1		M2	
Country	Interest elasticity	Standard error	Interest elasticity	Standard error
United States	0.23 (0.034)	2.4	0.24 (0.036)	2.2
1956–88		1.9		2.5
Japan	0.24 (0.075)	5.5	0.15 (0.062)	4.4
1968–88		4.6		3.8
Germany	0.22 (0.034)	3.3	0.16 (0.036)	3.0
1958–88		3.1		2.4
United Kingdom	0.25 (0.077)	5.2	0.12 (0.055)	4.6
1953–88		4.1		3.6
France	0.084 (0.042)	3.9	0.012 (0.061)	3.4
1952–88		4.4		2.7
Italy	0.19 (0.072)	5.1	0.14 (0.063)	4.5
1953–88 (M1)		3.6		3.7
1955–88 (M2)				
Canada	0.56 (0.12)	5.8	0.15 (0.069)	4.7
1950–88		5.1		4.3

Note: Standard errors are in parentheses. All "official" and robust estimates of the standard error of the forecasts are in percent.

the forecasts are purely ex ante and computed recursively without any smoothing. The stochastic trend does change over time, but the filter does not utilize future observations to fit a trend to the complete period; instead, it moves through the data and learns from the data how to adjust the trend as time proceeds.

The stochastic trend gives the Kalman filter its competitive edge over standard regression techniques, including the cointegration method with an error-correction step. Proponents of cointegration have to assume that all changes in the dependent variable that are not explained by a linear combination of the levels of the explanatory variables are stationary and can be taken care of in the error-correction step. This assumption, however, is implausible in cases, such as the demand for money, in which all the explanatory variables that are included do exhibit nonstationarity. It seems less than ideal to accept that the influences that can be measured (opportunity cost, possibly inflation or income) are nonstationary, but to assume that other factors for which there are no proper empirical measurements (innovations in payments techniques, development of new substitutes for money) are stationary, as required by the cointegration technique. The Kalman filter, by contrast, is designed to deal with nonstationarity of the unobserved components in the model.

The reasons for computing the forecasts conditional on the interest rate for the current year are twofold. First, the outcomes are directly comparable to results from studies of the demand for money, the principal differences being that the Kalman filter is an on-line technique instead of an ex post method, and allows for a stochastic trend in velocity. Second, because interest rates are observed without lag and without measurement error, policymakers can always adjust any targets for a monetary aggregate if interest rates during the planning period deviate from their predicted values when the targets were set. Hence, one could argue that forecasts conditional on interest rate realizations produce more useful evidence about the forecastability of velocity than forecasts that are conditional only on past values of velocity, income, and interest rates.

Table 2 gives two estimates of the accuracy of the forward Kalman filter. The first number for each country and each monetary aggregate indicates the root mean-square-error of the forecasts for the period as indicated. The second number is a robust estimate of that same root mean-square-error, computed using the median absolute deviation divided by the correction factor, 0.6745. For normally distributed values this robust estimate has the same expectation as the standard error. Outliers in the series cause the robust estimate to be smaller than the "official" standard error.

Table 2 confirms that outliers are important in several countries. Table 3 lists all outliers, defined as forecast errors (in percent) in excess of three times the robust estimate of the standard error of the forecasts for the country and aggregate concerned. Note that 2 out of the 12 outliers relate to years in the period 1980–88, which does not support the hypothesis that outliers became more frequent in the recent period.

Table 3. *Outliers in Excess of the Robust Estimate of the Standard Error*

Country	M1 Velocity (year)	M2 Velocity (year)
Japan	−16.2 (1971)	−11.2 (1971)
Germany	—	93.0 (1960)
United Kingdom	−16.3 (1963)	−14.5 (1972)
France	—	−10.9 (1987)
Italy	12.7 (1960) −13.5 (1970) 14.2 (1974)	13.5 (1960)
Canada	—	−11.1 (1954) 14.9 (1983)

III. Has Velocity Become More Unpredictable?

This section discusses a number of additional hypotheses regarding the unpredictability of velocity. In Table 4, I present results of a formal test to determine whether the forecasts of velocity have become more imprecise in the 1980s. For each country the two numbers in each cell in the table refer to the variance of the forecast errors over the period through 1979, and the variance of the forecast errors over the period 1980–88. Forecasts errors are taken from the final forward filter as discussed in Section I and use the current realization of the interest rate. The sum of squared forecast errors has been divided by $n - 1$, with n being the number of errors in the sample.

The results in Table 4 reject the notion that the income velocity of money became more unpredictable worldwide in the 1980s. The errors become larger in the United States and Canada, as well as for M2 in France—in each case, by a factor of approximately 2. On a formal F-test this is insufficient in all five instances to reject the null hypothesis that the variance of velocity has remained unchanged. Velocity of M2 in Italy is as predictable before 1980 as after. In the eight other cases, the forecast errors decline, sometimes by a very large margin.

If the variances are arranged for both M1 and M2 and both periods in order of magnitude across the countries, it can be seen that for M1 velocity, the median value of the variance falls from 26.7 to 10.3 and for M2 from 17.5 to 16.4. It is also interesting to note that before 1980, M2 velocity was less variable than M1 velocity in all seven countries, but during the 1980s it was less variable in four of the countries. Particularly small are the forecast errors in the 1980s for M2 velocity in Japan and Germany.

Table 4. *Forecast Errors in Velocity*

Country	M1	M2
United States	5.1/8.4	4.2/8.5
Japan	49.5/10.3	34.4/4.4
Germany	12.8/8.9	12.4/2.5
United Kingdom	27.5/30.9	24.8/16.4
France	18.4/7.1	10.0/19.5
Italy	30.5/18.1	22.4/19.3
Canada	26.7/69.0	17.5/45.7

Note: All numbers must be multiplied by 10^{-4}. The first number in each pair refers to the variance of the forecast errors before 1980; the second number, to the variance over 1980–88. Forecast errors are based on an on-line Kalman filter that uses the current value of the long-term government bond rate.

Table 5. *Forecast Errors for 1980–88*
(In percent)

Country	Kalman Filter		Regressions	
	Bias	Standard error	Bias	Standard error
United States				
M1	−1.46	2.09	2.48	2.15
M2	0.24	2.89	0.55	4.71
United Kingdom				
M1	−5.50	6.14	5.47	6.97[a]
M2	−1.98	4.20	6.06	4.52
France				
M1	0.25	2.69	−2.80	3.51
M2	−0.71	4.14	8.65	3.07
Italy				
M1	3.79	2.58	18.26	6.14
M2	4.16	2.94	15.26	4.03
Germany				
M1	−0.25	2.96	5.92	3.17
M2	0.05	1.81	3.74	1.07
Canada				
M1	−2.83	7.38	3.40	9.99
M2	1.39	6.61	−3.64	5.70

[a] The dummy variable for 1981 has not been inserted in the calculations for the United Kingdom.

Table 5 shows how the Kalman filter forecasts compare to an alternative method of generating forecasts of velocity. The Kalman filters have been re-estimated for periods through 1979 and extrapolated through 1988.[12] As an alternative, regressions have been performed for both monetary aggregates according to the following specification:

$$V_t = c + \alpha tr_t + \beta y_t + \theta i_t + u_t$$

$$u_t - \phi u_{t-1} = a_t. \tag{5}$$

In equation (5), velocity is regressed on a linear trend, on real income, and on the long-term interest rate. A first-order autoregressive parameter is estimated for the residuals in all cases. The equation is estimated using data through 1979, and the regression coefficients are used for dynamic forecasts conditional on the realized values of real income and

[12] Japan had to be omitted because of the limited length of the data series.

the interest rate, and again incorporating the serial correlation correction. The numbers in Table 5 show the mean errors (the bias) and the standard deviations of the conditional forecasts for 1980–88. The Kalman filter gives less biased forecasts with far lower forecast errors.

Finally, Table 6 investigates whether the differences in predictability of velocity across countries are related to the unpredictability of the money supplies. I have applied uniform Box-Jenkins time-series models to the money supply data, assuming a first-order moving average model applied to the second differences of money stock data. The table shows the estimated standard errors of the 14 Box-Jenkins models, together with the robust estimates of the standard errors of the forecasts in velocity. I have computed Spearman's rank correlation coefficients between these errors and the forecast errors for velocity. For both M1 and M2, the rank correlation coefficient equals 0.71, which is at the 0.05 significance level.

Table 6 investigates the rankings of the forecast errors in money and in velocity on a cross-sectional basis. One can also rank the forecast errors for money and velocity in each country in order to see whether years in

Table 6. *Forecast Errors in Money and Velocity*
(In percent)

Country	M1	Rank	M2	Rank
United States				
Velocity	1.90	1	2.50	2
Money	2.75	1	3.10	4
United Kingdom				
Velocity	4.10	4	3.60	4
Money	5.32	5	5.20	7
France				
Velocity	4.40	5	2.70	3
Money	3.48	2	2.83	2
Germany				
Velocity	3.10	2	2.40	1
Money	4.02	3	2.17	1
Italy				
Velocity	3.60	3	3.70	5
Money	4.42	4	3.13	5
Canada				
Velocity	5.10	7	4.30	7
Money	6.55	7	4.36	6
Japan				
Velocity	4.60	6	3.80	6
Money	5.37	6	2.96	3

which realized money growth deviated much from predicted money growth tended to be years in which velocity also deviated a lot from its conditional forecast.

Significant rank correlations at the 0.05 level, using Spearman's method, are obtained in the following cases: United Kingdom—M1 (0.60), and M2 (0.65); Japan—M1 (0.61); Italy—M1 (0.52), and M2 (0.37); and Canada—M1 (0.49), and M2 (0.55). There were no significant negative correlations. Hence, in the countries in which M1 or M2 velocity was most variable, years with large forecast errors in money tended to be years with large forecast errors in velocity.

IV. Conclusions

The Kalman filter results indicate a substantial interest rate elasticity of the demand for money for M1. Niskanen (1988) and Poole (1988) were the first economists to point out that earlier estimates of the demand for real balances in the United States might have gone astray by assuming that the secular increase in velocity during the 1970s should be represented by a linear trend. They pointed to the alternative hypothesis that the demand for money fell during that period because of higher trending interest rates. Poole's paper describes why a substantial interest rate elasticity makes the conduct of a disinflationary monetary policy more difficult: the rate of growth of the money supply has to decline in order to lower inflationary expectations, but as the lower inflationary expectations lead to lower long-term interest rates, the demand for real balances goes up.

The results lend no support to the hypothesis that the income velocity of money became significantly more unpredictable in the 1980s. Forecast errors did increase in the United States, but became smaller in most other countries. The frequency of outliers, defined as particularly large forecast errors, also did not increase during the years 1980–88. There is a significant correlation between the size of the forecast errors in velocity and the size of the forecast errors in money; predictable monetary policies are associated with predictable behavior of velocity.

Finally, regarding methodological issues, the Kalman filter allows us to specify the model in terms of levels, even though the dependent variable, the explanatory variables, and the error terms are nonstationary. The level specification has important advantages: smaller measurement errors in the dependent (and independent) variables; superior estimates of the coefficients, if the independent variable(s) affect velocity with a variable lag. Also, the Kalman filter has the advantage over the cointegration technique that no assumption needs to be made (and tested using weak power tests) about the degree of cointegration of the dependent and independent variables. If the hard-to-model effects on velocity of changes in payments techniques or the introduction of new money substitutes have persistent effects, the cointegration technique breaks down, but the Kalman filter can cope with such permanent shifts in the demand for money through its incorporation of a stochastic trend.

REFERENCES

Bomhoff Eduard J., "Predicting the Income Velocity of Money," (unpublished; Rotterdam: Erasmus University, 1990).

Boughton, James M., "Long-Run Money Demand in Large Industrial Countries," *Staff Papers,* International Monetary Fund, Vol. 38 (March 1991), pp. 1–32.

Bordo, Michael D., and Lars Jonung, *The Long-Run Behavior of the Velocity of Circulation: The International Evidence* (Cambridge; New York: Cambridge University Press, 1987).

Cooley, Thomas F., and Stephen F. LeRoy, "Identification and Estimation of Money Demand," *American Economic Review,* Vol. 71 (December 1981), pp. 825–44.

Dempster, A.P., N.N. Laird, and D.B. Rubin, "Maximum Likelihood from Incomplete Data via the EM Algorithm," *Journal of the Royal Statistical Society,* Series B, Vol. 39 (1977), pp. 1–22.

den Butter, Frank A.G., and Martin M.G. Fase, "The Demand for Money in E.E.C. Countries," *Journal of Monetary Economics,* Vol. 8 (September 1981), pp. 201–30.

Durlauf, Steven N., and Peter C.B. Phillips, "Trends Versus Random Walks in Time Series Analysis," *Econometrica,* Vol. 56 (November 1988), pp. 1333–54.

Granger, Clive W.J., and Paul Newbold, "Spurious Regressions in Econometrics," *Journal of Econometrics,* Vol. 2 (1974), pp. 111–20.

Hamilton, James D., "The Long-Run Behavior of the Velocity of Circulation: A Review Essay," *Journal of Monetary Economics,* Vol. 23 (March 1989), pp. 335–44.

Harvey, Andrew, *Forecasting, Structural Time Series Models, and the Kalman Filter* (Cambridge; New York: Cambridge University Press, 1989).

Hendry, David F., and Neil R. Ericsson, "An Econometric Analysis of U.K. Money Demand in *Monetary Trends in the United States and the United Kingdom* by Milton Friedman and Anna J. Schwartz," *American Economic Review,* Vol. 81 (March 1991), pp. 8–38.

Hetzel, Robert L., and Yash P. Mehra, "The Behavior of Money Demand in the 1980s," *Journal of Money, Credit and Banking,* Vol. 21 (November 1989), pp. 455–63.

Hoffman, Dennis, and Robert H. Rasche, "Long-Run Income and Interest Elasticity of Money Demand in the United States," NBER Working Paper, No. 2949 (Cambridge, Massachusetts: National Bureau of Economic Research, April 1989).

Maybeck, Peter S., "Stochastic Models, Estimation, and Control," Volume 1, *Mathematics in Science and Engineering* (Boston: Academic Press, 1979), pp. 141–42.

———, "Stochastic Models, Estimation, and Control," Volume 2, *Mathematics in Science and Engineering* (Boston: Academic Press, 1982), pp. 141–42.

Nelson, Charles R., "Spurious Trend and Cycle in the State Space Decomposition of a Time Series with a Unit Root," *Journal of Economic Dynamics and Control,* Vol. 12 (June-September 1988), pp. 475–88.

———, and Charles I. Plosser, "Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications," *Journal of Monetary Economics,* Vol. 10 (September 1982), pp. 139–62.

Niskanen, William A., "Comment on Jean Waelbroeck," in *Macro and Micro Policies for More Growth and Employment, Symposium 1987,* ed. by Herbert Giersch (Tübingen: J.C.B. Mohr, 1988).

Plosser, Charles I., and G. William Schwert, "Money, Income, and Sunspots: Measuring Economic Relationships and the Effects of Differencing," *Journal of Monetary Economics,* Vol. 4 (November 1979), pp. 637–60.

Poole, William, "Monetary Policy Lessons of Recent Inflation and Disinflation," *Journal of Economic Perspectives,* Vol. 2 (Summer 1988), pp. 73–100.

Rasche, Robert H., "M1-Velocity and Money Demand Functions: Do Stable Relationships Exist?," in *Empirical Studies of Velocity, Real Exchange Rates, Unemployment and Productivity,* ed. by Allan H. Meltzer and Karl Brunner, Carnegie-Rochester Conference Series on Public Policy, Vol. 27 (Amsterdam; New York: North-Holland, 1987).

Shumway, Robert H., and D.S. Stoffer, "An Approach to Time Series Smoothing and Forecasting Using the EM Algorithm," *Journal of Time Series Analysis,* Vol. 3, No. 4 (1982), pp. 253–64.

Swamy, PA.V.B., Peter von zur Muehlen, and J.S. Mehta, "Co-Integration: Is It a Property of the Real World," (Washington: Board of Governors of the Federal Reserve System, 1989).

Reprint Series, CentER, Tilburg University, The Netherlands:

No. 1 G. Marini and F. van der Ploeg, Monetary and fiscal policy in an optimising model with capital accumulation and finite lives, The Economic Journal, vol. 98, no. 392, 1988, pp. 772 - 786.

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No. 3 A.P. Barten, The history of Dutch macroeconomic modelling (1936-1986), in W. Driehuis, M.M.G. Fase and H. den Hartog (eds.), Challenges for Macroeconomic Modelling, Contributions to Economic Analysis 178, Amsterdam: North-Holland, 1988, pp. 39 - 88.

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No. 6 E. van Damme, Renegotiation-proof equilibria in repeated prisoners' dilemma, Journal of Economic Theory, vol. 47, no. 1, 1989, pp. 206 - 217.

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No. 8 Th. van de Klundert and F. van der Ploeg, Wage rigidity and capital mobility in an optimizing model of a small open economy, De Economist 137, nr. 1, 1989, pp. 47 - 75.

No. 9 G. Dhaene and A.P. Barten, When it all began: the 1936 Tinbergen model revisited, Economic Modelling, vol. 6, no. 2, 1989, pp. 203 - 219.

No. 10 F. van der Ploeg and A.J. de Zeeuw, Conflict over arms accumulation in market and command economies, in F. van der Ploeg and A.J. de Zeeuw (eds.), Dynamic Policy Games in Economics, Contributions to Economic Analysis 181, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1989, pp. 91 - 119.

No. 11 J. Driffill, Macroeconomic policy games with incomplete information: some extensions, in F. van der Ploeg and A.J. de Zeeuw (eds.), Dynamic Policy Games in Economics, Contributions to Economic Analysis 181, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1989, pp. 289 - 322.

No. 12 F. van der Ploeg, Towards monetary integration in Europe, in P. De Grauwe e.a., De Europese Monetaire Integratie: vier visies, Wetenschappelijke Raad voor het Regeringsbeleid V 66, 's-Gravenhage: SDU uitgeverij, 1989, pp. 81 - 106.

No. 13 R.J.M. Alessie and A. Kapteyn, Consumption, savings and demography, in A. Wenig, K.F. Zimmermann (eds.), Demographic Change and Economic Development, Berlin/Heidelberg: Springer-Verlag, 1989, pp. 272 - 305.

No. 14 A. Hoque, J.R. Magnus and B. Pesaran, The exact multi-period mean-square forecast error for the first-order autoregressive model, Journal of Econometrics, vol. 39, no. 3, 1988, pp. 327 - 346.

No. 15 R. Alessie, A. Kapteyn and B. Melenberg, The effects of liquidity constraints on consumption: estimation from household panel data, European Economic Review 33, no. 2/3, 1989, pp. 547 - 555.

No. 16 A. Holly and J.R. Magnus, A note on instrumental variables and maximum likelihood estimation procedures, Annales d'Économie et de Statistique, no. 10, April-June, 1988, pp. 121 - 138.

No. 17 P. ten Hacken, A. Kapteyn and I. Woittiez, Unemployment benefits and the labor market, a micro/macro approach, in B.A. Gustafsson and N. Anders Klevmarken (eds.), The Political Economy of Social Security, Contributions to Economic Analysis 179, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1989, pp. 143 - 164.

No. 18 T. Wansbeek and A. Kapteyn, Estimation of the error-components model with incomplete panels, Journal of Econometrics, vol. 41, no. 3, 1989, pp. 341 - 361.

No. 19 A. Kapteyn, P. Kooreman and R. Willemse, Some methodological issues in the implementation of subjective poverty definitions, The Journal of Human Resources, vol. 23, no. 2, 1988, pp. 222 - 242.

No. 20 Th. van de Klundert and F. van der Ploeg, Fiscal policy and finite lives in interdependent economies with real and nominal wage rigidity, Oxford Economic Papers, vol. 41, no. 3, 1989, pp. 459 - 489.

No. 21 J.R. Magnus and B. Pesaran, The exact multi-period mean-square forecast error for the first-order autoregressive model with an intercept, Journal of Econometrics, vol. 42, no. 2, 1989, pp. 157 - 179.

No. 22 F. van der Ploeg, Two essays on political economy: (i) The political economy of overvaluation, The Economic Journal, vol. 99, no. 397, 1989, pp. 850 - 855; (ii) Election outcomes and the stockmarket, European Journal of Political Economy, vol. 5, no. 1, 1989, pp. 21 - 30.

No. 23 J.R. Magnus and A.D. Woodland, On the maximum likelihood estimation of multivariate regression models containing serially correlated error components, International Economic Review, vol. 29, no. 4, 1988, pp. 707 - 725.

No. 24 A.J.J. Talman and Y. Yamamoto, A simplicial algorithm for stationary point problems on polytopes, Mathematics of Operations Research, vol. 14, no. 3, 1989, pp. 383 - 399.

No. 25 E. van Damme, Stable equilibria and forward induction, Journal of Economic Theory, vol. 48, no. 2, 1989, pp. 476 - 496.

No. 26 A.P. Barten and L.J. Bettendorf, Price formation of fish: An application of an inverse demand system, European Economic Review, vol. 33, no. 8, 1989, pp. 1509 - 1525.

No. 27 G. Noldeke and E. van Damme, Signalling in a dynamic labour market, Review of Economic Studies, vol. 57 (1), no. 189, 1990, pp. 1 - 23

No. 28 P. Kop Jansen and Th. ten Raa, The choice of model in the construction of input-output coefficients matrices, International Economic Review, vol. 31, no. 1, 1990, pp. 213 - 227.

No. 29 F. van der Ploeg and A.J. de Zeeuw, Perfect equilibrium in a model of competitive arms accumulation, International Economic Review, vol. 31, no. 1, 1990, pp. 131 - 146.

No. 30 J.R. Magnus and A.D. Woodland, Separability and aggregation, Economica, vol. 57, no. 226, 1990, pp. 239 - 247.

No. 31 F. van der Ploeg, International interdependence and policy coordination in economies with real and nominal wage rigidity, Greek Economic Review, vol. 10, no. 1, June 1988, pp. 1 - 48.

No. 32 E. van Damme, Signaling and forward induction in a market entry context, Operations Research Proceedings 1989, Berlin-Heidelberg: Springer-Verlag, 1990, pp. 45 - 59.

No. 33 A.P. Barten, Toward a levels version of the Rotterdam and related demand systems, Contributions to Operations Research and Economics, Cambridge: MIT Press, 1989, pp. 441 - 465.

No. 34 F. van der Ploeg, International coordination of monetary policies under alternative exchange-rate regimes, Advanced Lectures in Quantitative Economics, London-Orlando: Academic Press Ltd., 1990, pp. 91 - 121.

No. 35 Th. van de Klundert, On socioeconomic causes of 'wait unemployment', European Economic Review, vol. 34, no. 5, 1990, pp. 1011 - 1022.

No. 36 R.J.M. Alessie, A. Kapteyn, J.B. van Lochem and T.J. Wansbeek, Individual effects in utility consistent models of demand, in J. Hartog, G. Ridder and J. Theeuwes (eds.), Panel Data and Labor Market Studies, Amsterdam: Elsevier Science Publishers B.V. (North-Holland), 1990, pp. 253 - 278.

No. 37 F. van der Ploeg, Capital accumulation, inflation and long-run conflict in international objectives, Oxford Economic Papers, vol. 42, no. 3, 1990, pp. 501 - 525.

No. 38 Th. Nijman and F. Palm, Parameter identification in ARMA Processes in the presence of regular but incomplete sampling, Journal of Time Series Analysis, vol. 11, no. 3, 1990, pp. 239 - 248.

No. 39 Th. van de Klundert, Wage differentials and employment in a two-sector model with a dual labour market, Metroeconomica, vol. 40, no. 3, 1989, pp. 235 - 256.

No. 40 Th. Nijman and M.F.J. Steel, Exclusion restrictions in instrumental variables equations, Econometric Reviews, vol. 9, no. 1, 1990, pp. 37 - 55.

No. 41 A. van Soest, I. Woittiez and A. Kapteyn, Labor supply, income taxes, and hours restrictions in the Netherlands, Journal of Human Resources, vol. 25, no. 3, 1990, pp. 517 - 558.

No. 42 Th.C.M.J. van de Klundert and A.B.T.M. van Schaik, Unemployment persistence and loss of productive capacity: a Keynesian approach, Journal of Macroeconomics, vol. 12, no. 3, 1990, pp. 363 - 380.

No. 43 Th. Nijman and M. Verbeek, Estimation of time-dependent parameters in linear models using cross-sections, panels, or both, Journal of Econometrics, vol. 46, no. 3, 1990, pp. 333 - 346.

No. 44 E. van Damme, R. Selten and E. Winter, Alternating bid bargaining with a smallest money unit, Games and Economic Behavior, vol. 2, no. 2, 1990, pp. 188 - 201.

No. 45 C. Dang, The D_1-triangulation of π^n for simplicial algorithms for computing solutions of nonlinear equations, Mathematics of Operations Research, vol. 16, no. 1, 1991, pp. 148 - 161.

No. 46 Th. Nijman and F. Palm, Predictive accuracy gain from disaggregate sampling in ARIMA models, Journal of Business & Economic Statistics, vol. 8, no. 4, 1990, pp. 405 - 415.

No. 47 J.R. Magnus, On certain moments relating to ratios of quadratic forms in normal variables: further results, Sankhya: The Indian Journal of Statistics, vol. 52, series B, part. 1, 1990, pp. 1 - 13.

No. 48 M.F.J. Steel, A Bayesian analysis of simultaneous equation models by combining recursive analytical and numerical approaches, Journal of Econometrics, vol. 48, no. 1/2, 1991, pp. 83 - 117.

No. 49 F. van der Ploeg and C. Withagen, Pollution control and the ramsey problem, Environmental and Resource Economics, vol. 1, no. 2, 1991, pp. 215 - 236.

No. 50 F. van der Ploeg, Money and capital in interdependent economies with overlapping generations, Economica, vol. 58, no. 230, 1991, pp. 233 - 256.

No. 51 A. Kapteyn and A. de Zeeuw, Changing incentives for economic research in the Netherlands, European Economic Review, vol. 35, no. 2/3, 1991, pp. 603 - 611.

No. 52 C.G. de Vries, On the relation between GARCH and stable processes, Journal of Econometrics, vol. 48, no. 3, 1991, pp. 313 - 324.

No. 53 R. Alessie and A. Kapteyn, Habit formation, interdependent preferences and demographic effects in the almost ideal demand system, The Economic Journal, vol. 101, no. 406, 1991, pp. 404 - 419.

No. 54 W. van Groenendaal and A. de Zeeuw, Control, coordination and conflict on international commodity markets, Economic Modelling, vol. 8, no. 1, 1991, pp. 90 - 101.

No. 55 F. van der Ploeg and A.J. Markink, Dynamic policy in linear models with rational expectations of future events: A computer package, Computer Science in Economics and Management, vol. 4, no. 3, 1991, pp. 175 - 199.

No. 56 H.A. Keuzenkamp and F. van der Ploeg, Savings, investment, government finance, and the current account: The Dutch experience, in G. Alogoskoufis, L. Papademos and R. Portes (eds.), External Constraints on Macroeconomic Policy: The European Experience, Cambridge: Cambridge University Press, 1991, pp. 219 - 263.

No. 57 Th. Nijman, M. Verbeek and A. van Soest, The efficiency of rotating-panel designs in an analysis-of-variance model, Journal of Econometrics, vol. 49, no. 3, 1991, pp. 373 - 399.

No. 58 M.F.J. Steel and J.-F. Richard, Bayesian multivariate exogeneity analysis - an application to a UK money demand equation, Journal of Econometrics, vol. 49, no. 1/2, 1991, pp. 239 - 274.

No. 59 Th. Nijman and F. Palm, Generalized least squares estimation of linear models containing rational future expectations, International Economic Review, vol. 32, no. 2, 1991, pp. 383 - 389.

No. 60 E. van Damme, Equilibrium selection in 2 x 2 games, Revista Espanola de Economia, vol. 8, no. 1, 1991, pp. 37 - 52.

No. 61 E. Bennett and E. van Damme, Demand commitment bargaining: the case of apex games, in R. Selten (ed.), Game Equilibrium Models III - Strategic Bargaining, Berlin: Springer-Verlag, 1991, pp. 118 - 140.

No. 62 W. Güth and E. van Damme, Gorby games - a game theoretic analysis of disarmament campaigns and the defense efficiency - hypothesis -, in R. Avenhaus, H. Karkar and M. Rudnianski (eds.), Defense Decision Making - Analytical Support and Crisis Management, Berlin: Springer-Verlag, 1991, pp. 215 - 240.

No. 63 A. Roell, Dual-capacity trading and the quality of the market, Journal of Financial Intermediation, vol. 1, no. 2, 1990, pp. 105 - 124.

No. 64 Y. Dai, G. van der Laan, A.J.J. Talman and Y. Yamamoto, A simplicial algorithm for the nonlinear stationary point problem on an unbounded polyhedron, Siam Journal of Optimization, vol. 1, no. 2, 1991, pp. 151 - 165.

No. 65 M. McAleer and C.R. McKenzie, Keynesian and new classical models of unemployment revisited, The Economic Journal, vol. 101, no. 406, 1991, pp. 359 - 381.

No. 66 A.J.J. Talman, General equilibrium programming, Nieuw Archief voor Wiskunde, vol. 8, no. 3, 1990, pp. 387 - 397.

No. 67 J.R. Magnus and B. Pesaran, The bias of forecasts from a first-order autoregression, Econometric Theory, vol. 7, no. 2, 1991, pp. 222 - 235.

No. 68 F. van der Ploeg, Macroeconomic policy coordination issues during the various phases of economic and monetary integration in Europe, European Economy - The Economics of EMU, Commission of the European Communities, special edition no. 1, 1991, pp. 136 - 164.

No. 69 H. Keuzenkamp, A precursor to Muth: Tinbergen's 1932 model of rational expectations, The Economic Journal, vol. 101, no. 408, 1991, pp. 1245 - 1253.

No. 70 L. Zou, The target-incentive system vs. the price-incentive system under adverse selection and the ratchet effect, Journal of Public Economics, vol. 46, no. 1, 1991, pp. 51 - 89.

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